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(54) LASER AND LASER WELDING METHOD

LASER UND LASERSCHWEISSENVERFAHREN

LASER ET PROCEDE DE SOUDAGE AU LASER

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Description

The present invention relates to a laser apparatus and a laser beam welding method of welding a surface-treated metal, and more particularly, to a laser apparatus and a laser beam welding method of welding a zinc-plated steel sheet with laser beams.

The increasing output of laser oscillators has led to an expansion of the fields of application for laser beam welding, which uses laser beams in place of the conventional gas welding or electrical welding. In particular, there is a strong demand for the capability to weld superimposed steel sheets and the like in the automobile industry. Namely, the steel sheets used in the automobile industry are zinc-plated steel sheets treated with zinc plating for the purpose of rust prevention, and a stable and high-speed laser beam welding of such zinc-plated steel sheets and the like is now required.

When welding superimposed zinc-plated steel sheets, however, a surface plating layer on the steel sheet is evaporated when irradiated with a laser beam, causing the generation of many blowholes. In particular, if there is no gap between the steel sheets, the steam of evaporated zinc blows off the molten base metal, making welding impossible. This is considered to be because zinc has a lower boiling point than the melting point of iron, and because the evaporating pressure is high, thus causing the molten iron to be blown off.

Accordingly, when welding superimposed zinc-plated steel sheets, a gap of a few hundred microns is provided between the steel sheets to allow the zinc steam generated on the surfaces thereof to escape. Nevertheless, it is extremely difficult to maintain the gap at a fixed value, at an actual production site, and thus the laser beam welding must be carried out while the steel sheets are in close contact with one another.

An object of the present invention is to provide a laser apparatus capable of producing a stable welding of surface-treated metals such as zinc-plated steel sheets while such sheets are in close contact with one another.

Another object of the present invention is to provide a laser beam welding method permitting a laser beam welding during which the occurrence of blowholes on surface-treated metals such as zinc-plated steel sheets is kept to a minimum.

JP-A-62-254992 discloses the welding of an aluminium member using a mixture containing oxygen as a shielding gas.

JP-A-1-44296 discloses a welding device in which an assist gas is automatically controlled.

DE-A-3926781 discloses a laser apparatus for welding a surface-treated metal coated with a material having an evaporation temperature lower than a melting point of the surface-treated metal, by using a continuous wave or pulse wave laser beam, the laser apparatus comprising: a gas supply unit for supplying oxygen and another gas as an auxiliary gas; and an auxiliary gas jetting unit for jetting the auxiliary gas to a welding spot; and according to a first aspect of the present invention, such an apparatus is characterised in that the laser apparatus comprises a gas mixer in which the oxygen and the another gas are mixed before use in the auxiliary gas jetting unit.

DE-A-3926781 further discloses a method of welding a surface-treated metal coated with a material having an evaporation temperature lower than a melting point of the surface-treated metal, by using a continuous wave or pulse wave laser beam, wherein a mixture of oxygen and another gas is used as an auxiliary gas when welding; and according to a second aspect of the present invention, such a method is characterised in that the oxygen and the another gas are mixed in a mixer before being used as the auxiliary gas.

Conventionally, oxygen gas is not used for welding because it will ignite the iron, but when a laser beam is irradiated onto a surface-treated metal such as a zinc-plated steel sheet in an atmosphere of an auxiliary gas including oxygen gas or a mixture of oxygen gas and another gas, the material is ignited and forms a molten pool of a mixture of oxygen and iron. Such a molten pool has a low viscosity, allowing an easy escape of zinc steam.

Further, oxygen and zinc react to produce zinc oxide or zinc peroxide rather than steam, and therefore, when a laser beam passes therethrough, the iron oxide is separated as slag on the surface of the steel sheet, and an unoxidized part of the molten iron is solidified, to thereby obtain a strong weld. The zinc layer of the zinc-plated steel sheet is thinner than the steel sheet, and thus has no affect on the strength thereof after welding.

Furthermore, the heat generated by the reaction between oxygen and iron makes a significant contribution to the welding, and as the type of reaction that takes place depends on the concentration of oxygen gas, the type of other gas used, the beam focusing method, the pulse irradiation, and other conditions, the presence of oxygen gas provides the required effect.

Accordingly, the laser apparatus is equipped with a gas supply unit for supplying oxygen gas when conducting a laser beam welding.

In the accompanying drawings:

FIG. 1 is an external view of a laser apparatus of an embodiment according to the present invention;
FIG. 2 shows welding conditions of the embodiment, FIG. 2(A) being a view observed from the side with respect to the direction of advance of a machining head, and FIG. 2(B) being a view observed from the front with respect to the direction of advance of the machining head;
FIG. 3 shows surface welded conditions when oxygen gas is not used, FIG. 3(A) being a view observed from the side with respect to the direction of advance of the machining head, and FIG. 3(B) being a view observed from the front with respect to the direction of advance of the machining head;
FIG. 4 shows surface conditions of a welded spot in

the present embodiment, FIG. 4(A) illustrating a condition of the back surface, and FIG. 4(B) illustrating a condition of the top surface;

FIG. 5 shows surface conditions of a welded spot when oxygen gas is not used, FIG. 5(A) illustrating a condition of the back surface, and FIG. 5(B) illustrating a condition of the top surface;

FIG. 6 shows an example wherein three zinc-plated steel sheets are superimposed one on the other and then welded;

FIG. 7 illustrates the second embodiment of the present invention;

FIG. 8 illustrates an optimum range of a mixing proportion of an auxiliary gas in relation to a table feed speed;

FIG. 9 illustrates an optimum range of the mixing proportion of the auxiliary gas in relation to the thickness of a zinc-plating layer; and

FIG. 10 illustrates an optimum range of the flow rate of the auxiliary gas in relation to the table feed speed.

An embodiment of the present invention will now be described with reference to the accompanying drawings.

FIG. 1 is the external view of the laser apparatus according to an embodiment of the present invention. As shown in the figure, a laser beam 1 is passed through and focused by a lens 2, is output through a nozzle 8, and is irradiated onto zinc-plated steel sheets 3a and 3b. The lens 2 is fixed to a machining head 7, and the zinc-plated steel sheets 3a and 3b are fixed to a table 10e by claims 10a, 10b, 10c, and 10d.

Oxygen gas and argon gas are supplied from an oxygen (O_2) gas cylinder 4a and an argon (Ar) gas cylinder 4b via hoses 5a and 5b, respectively, and are mixed in a mixer 6 before being supplied to the machining head 7 via a hose 5c, to be then jetted through the nozzle 8 onto a machining spot 9.

The oxygen gas combines with zinc to produce zinc oxide and zinc peroxide, which are solids and suppress zinc evaporation, to thus control the generation of blowholes, and further, the heat generated by this combination facilitates the welding.

In this case, the thickness of the zinc-plated steel sheets 3a and 3b is 0.9 mm, the laser output is 3 kW, the feeding speed is 1.5 m/min., the ratio of the oxygen gas to the argon gas is 4:1, and the total volume of the auxiliary gas is 20 L/min. The laser beam is a pulse wave type.

FIG. 2 illustrates the welding conditions according to the present embodiment; wherein FIG. 2(A) is a view observed from the side with respect to the direction of advance of the machining head 7, and FIG. 2(B) is a view observed from the front with respect to the direction of advance of the machining head 7. In this example, fumes (clouds of a gas that has been evaporated and ionized) 11 and 12 are generated over the zinc-plated steel sheet 3a and under the zinc-plated steel sheet 3b. Also, spatters (molten lumps of metal sprung out) 13 and 14 are produced at the top and bottom, but the volume thereof is low.

FIG. 3 illustrates the conditions of a welded surface when oxygen gas is not used; wherein FIG. 3(A) is a view observed from the side with respect to the direction of advance of the machining head 7, and FIG. 3(B) is a view observed from the front with respect to the direction of advance of the machining head 7. In this example, fumes (clouds of a gas that has been evaporated and ionized) 11 and 12 are generated over the zinc-plated steel sheet 3a and under the zinc-plated steel sheet 3b, and further, spatters (molten lumps of metal sprung out) 13 and 14 are produced at the top and bottom; in this case, the volume thereof is very high.

Namely, as obvious from FIG. 2 and FIG. 3, it is possible to control the evaporation of zinc and to control spatters by mixing oxygen gas with the auxiliary gas.

FIG. 4 illustrates the surface conditions of a welded spot according to the present embodiment; wherein FIG. 4(A) shows the condition of the back surface, and FIG. 4(B) shows the condition of the top surface. As shown in the figures, parts 22a and 22b composed of a deep-yellow powder and parts 21a and 21b composed of a light-yellow powder are generated on either side of a bead 23. FIG. 4(B) shows that the bead 23 has a partly developed slag 25. As can be seen, in this example very few blowholes are generated.

FIG. 5 illustrates the surface conditions of a welded spot when oxygen gas is not used; wherein FIG. 5(A) shows the condition of the back surface, and FIG. 5(B) shows the condition of the top surface. As shown in the figures, parts 22a and 22b composed of a deep-yellow powder and parts 21a and 21b composed of a light-yellow powder are generated on either side of the bead 23. As can be seen, in this case many non-through blowholes 26 and through blowholes 27 are generated in the bead 23, and further, a black powder 28, which indicates the presence of zinc and carbide, is produced and many traces of spatter 29 can be observed.

Therefore, as is obvious from FIG. 4 and FIG. 5, the use of an auxiliary gas that is a mixture of oxygen gas and argon gas produces a stable welding while keeping the generation of blowholes to a minimum.

An increase in the proportion of oxygen in accordance with an increase in the welding speed produces a better effect, and it is also necessary to increase the proportion of oxygen in accordance with an increase in the output power. Note, the same effect can be obtained with helium gas, nitrogen gas or a mixture of one of these two gases with oxygen, instead of argon gas. Further, since the thickness of the zinc of the zinc-plated steel sheet is small, problems with the welding strength due to slag produced due to the use of oxygen will not arise.

FIG. 6 illustrates an example in which three zinc-plated steel sheets are superimposed one on the other and then welded. Here, although three zinc-plated steel sheets 33a, 33b, and 33c are superimposed, only the

zinc-plated steel sheets 33a and 33b are melted to form a bead 34. As can be seen, portion 32 subjected to thermal influences is produced outside of a molten portion 31, but no thermal influence is applied to the zinc-plated steel sheet 33c. This welding operation is performed by selecting the output power of the laser beam, the frequency, the duty ratio, and the welding speed according to need. Note, as the welding operation does not thermally affect the zinc-plated steel sheet 33c, it can be effectively used for welding a spot or the like where a thermal influence must not be applied to a surface opposite to the welded surface.

FIG. 7 illustrates the second embodiment of the present invention. As shown in the drawing, a laser beam 1 emitted from a laser oscillator 20 is guided to a machining head 7 through a circular polarimeter 21 and plane mirrors 24a and 24b. The laser beam 1 is then passed through and focused by a lens 2 and irradiated onto zinc-plated steel sheets 3a and 3b, to thereby carry out a laser welding thereof. At the same time, oxygen gas and argon gas are introduced from an oxygen gas cylinder 4a and an argon gas cylinder 4b, respectively, are passed through control valves 30a and 30b, respectively, into a mixer 6, and are then mixed together before being supplied as an auxiliary gas to a nozzle 8, through a gas inlet 70 of the machining head 7, and jetted onto a machining spot 9.

An NC device 50 controls the laser oscillator 20 and drives servomotors 11a and 11b of a table 10, through a machining program. Further, the NC device calculates the mixing proportion and flow rate of the auxiliary gas according to data stored in a memory 51, and drives the control valves 30a and 30b in accordance with the results of the calculation. This procedure ensures a supply of the auxiliary gas having an optimum mixing proportion and flow rate at all times, to thereby carry out a good laser welding.

The following is an explanation of the optimum welding condition ranges of the auxiliary gas. Here, the optimum ranges refer to ranges within which blowholes are not produced and slag is kept to a minimum.

FIG. 8 illustrates an optimum mixing proportion range of the auxiliary gas in relation to the table feeding speed. As shown in the figure, a mixing ratio R (= $Ar/(Ar + O_2)$) of the auxiliary gas in an optimum range 60 is lowered as the feeding speed (welding speed) F of the table 10 is increased; this means that it is necessary to increase the proportion of oxygen in the auxiliary gas as the feeding speed F is increased.

FIG. 9 illustrates an optimum mixing proportion range of the auxiliary gas in relation to the thickness of a zinc plating layer. As shown in the figure, the mixing ratio R (= $Ar/(Ar + O_2)$) of the auxiliary gas in an optimum range 61 is lowered as a thickness t of the zinc plating layer is increased; this means that it is necessary to increase the proportion of oxygen in the auxiliary gas as the thickness t of the zinc plating layer is increased.

FIG. 10 illustrates an optimum flow rate range of the auxiliary gas in relation to the table feeding speed. As shown in the figure, it is necessary to increase a flow rate L of the auxiliary gas as the feeding speed F is increased, but the feeding speed F has an upper limit, and therefore, no further effect is obtained even when the flow rate L is increased, if the upper limit thereof is exceeded. In such a case, another parameter, such as the mixing ratio R, must be changed. Data related to the optimum ranges of the auxiliary gas in relation to the aforementioned welding conditions is stored in the memory 51 of the NC device 50, and is used for controlling the mixing ratio R or the like of the auxiliary gas.

In the foregoing description, zinc-plated steel sheets are used as the welding material, but obviously the same applies to other surface-treated metals coated with materials having melting points lower than those of the metals.

Further, in the above description, oxygen gas and another gas are mixed in the mixer 6, but the same effect also can be obtained by supplying the oxygen gas and another gas directly to the nozzle, and jetting the gases directly onto a welding spot.

Furthermore, the feeding speed (welding speed), output power, and the thickness of the zinc plating layer are used as the parameters (welding conditions) determining the mixing ratio and flow rate of the auxiliary gas, but other parameters such as the type of coating material (e.g., zinc + nickel, alloy) and the shape of a welding bead also may be used.

Also, a continuous wave type laser beam may be used instead of the pulse wave type.

As described above, in the laser apparatus oxygen gas is mixed in the auxiliary gas to thereby obtain a stable welding with a minimization of blowholes, without the need to provide a gap between the surface-treated metals. Similarly, a laser beam welding method wherein oxygen is mixed in the auxiliary gas is employed, and thus the occurrence of blowholes is kept to a minimum. Further, an auxiliary gas having an optimum mixing ratio and flow rate is supplied, to thereby ensure a good laser beam welding operation.

Claims

1. A laser apparatus for welding a surface-treated metal (3a,3b) coated with a material having an evaporation temperature lower than a melting point of the surface-treated metal, by using a continuous wave or pulse wave laser beam (1), the laser apparatus comprising: a gas supply unit (4a,4b) for supplying oxygen and another gas as an auxiliary gas; and an auxiliary gas jetting unit (7,8) for jetting the auxiliary gas to a welding spot; characterised in that the laser apparatus comprises a gas mixer (6) in which the oxygen and the another gas are mixed before use in the auxiliary gas jetting unit (6,7).

2. An apparatus according to claim 1, wherein the another gas contains at least one of argon gas,

helium gas and nitrogen gas.

3. An apparatus according to claim 1 or claim 2, wherein the oxygen and another gas are supplied through control valves (30a,30b), respectively.

4. An apparatus according to claim 3, wherein the mixing proportion of the oxygen and another gas, and the flow rates of each of the oxygen and another gas are controlled by a degree of opening of the control valves (30a,30b).

5. An apparatus according to any one of the preceding claims, wherein the control valves are controlled by an NC device (50).

6. A method of welding a surface-treated metal (3a,3b) coated with a material having an evaporation temperature lower than a melting point of the surface-treated metal, by using a continuous wave or pulse wave laser beam (1), wherein a mixture of oxygen and another gas is used as an auxiliary gas when welding; characterised in that the oxygen and the another gas are mixed in a mixer (6) before being used as the auxiliary gas.

7. A method according to claim 6, wherein the another gas is at least one of argon gas, helium gas, and nitrogen gas.

8. A method according to claim 6 or claim 7, wherein the surface-treated metal is a zinc-plated steel sheet (3a,3b).

9. A method according to any one of claims 6 to 8, wherein the proportion of oxygen is increased as the welding speed is increased.

10. A method according to any one of claims 6 to 9, wherein the proportion of oxygen is increased as the laser output is increased.

11. A method according to any one of claims 6 to 10, wherein three sheets (33a,33b,33c) of surface-treated metal are superimposed on one another and then welded in such a manner that a bottom sheet (33c) of superimposed three sheets of surface-treated metal is not melted.

12. A method according to any one of claims 6 to 11, wherein the mixing ratio of the oxygen and another gas, and the flow rates of each of the oxygen and another gas are controlled in accordance with at least the thickness of a coating layer of the surface-treated metal, the type of coating material, and the shape of a welding bead.

Patentansprüche

1. Laser zum Schweißen von oberflächenbehandeltem Metall (3a,3b), das mit einem Werkstoff beschichtet ist, der eine kleinere Verdampfungstemperatur als der Schmelzpunkt des oberflächenbehandelten Metalls hat, unter Verwendung eines kontinuierlichen Wellen- oder Impulswellen-Laserstrahls (1), wobei der Laser aufweist: eine Gaszufuhr (4a,4b) zum Zuführen von Sauerstoff und einem weiteren Gas als Hilfsgas; und eine Ausstoßeinheit (7,8) zum Ausstoßen des Hilfsgases auf eine Schweißstellen, dadurch gekennzeichnet, daß der Laser ferner einen Gasmischer (6) aufweist, in dem der Sauerstoff und das weitere Gas gemischt werden, bevor sie in die Ausstoßeinheit (6,7) gelangen.

2. Laser nach Anspruch 1, bei dem das weitere Gas mindestens Argongas, Heliumgas oder Stickstoffgas enthält.

3. Laser nach Anspruch 1 oder 2, bei dem der Sauerstoff und das weitere Gas über Ventile (30a,30b) zugeführt werdebn.

4. Laser nach Anspruch 3, bei dem der Mischanteil des Sauerstoffs und des weiteren Gases und das Durchflußvolumen jeweils von Sauerstoffgas und dem weiteren Gas durch den Öffnungsgrad der Ventile (30a,30b) gesteuert werden.

5. Laser nach einem der vorhergehenden Ansprüche, bei dem die Ventile von einer numerischen Steuerung (50) angesteuert werden.

6. Verfahren zum Schweißen von oberflächenbehandeltem Metall (3a,3b), das mit einem Werkstoff beschichtet ist, der eine kleinere Verdampfungstemperatur als der Schmelzpunkt des oberflächenbehandelten Metalls hat, unter Verwendung eines kontinuierlichen Wellen- oder Impulswellen-Laserstrahls (1), wobei eine Mischung aus Sauerstoff und einem weiteren Gas als Hilfsgas beim Schweißen benutzt wird, dadurch gekennzeichnet, daß der Sauerstoff und das weitere Gas in einem Mischer (6) gemischt werden, bevor sie als Hilfsgas verwendet werden.

7. Verfahren nach Anspruch 6, bei dem das weitere Gas mindestens Argongas, Heliumgas oder Stickstoffgas ist.

8. Verfahren nach Anspruch 6 oder 7, bei dem das oberflächenbehandelte Metall ein verzinktes Stahlblech (3a,3b) ist.

9. Verfahren nach einem der Ansprüche 6 bis 8, bei dem der Anteil des Sauerstoffs vergrößert wird,

wenn die Schweißgeschwindigkeit ansteigt.

10. Verfahren nach einem der Ansprüche 6 bis 9, bei dem der Anteil des Sauerstoffs vergrößert wird, wenn die Laserleistung ansteigt.

11. Verfahren nach einem der Ansprüche 6 bis 10, bei dem drei Bleche (33a, 33b, 33c) oberflächenbehandelten Metalls aufeinander gestapelt und dann derart verschweißt werden, daß ein Bodenblech (33c) der drei gestapelten oberflächenbehandelten Bleche nicht angeschmolzen wird.

12. Verfahren nach einem der Ansprüche 6 bis 11; bei dem das Mischungsverhältnis von Sauerstoff und weiteren Gases und die Durchflußvolumen sowohl von Sauerstoff als auch dem weiteren Gas entsprechend mindestens der Dicke der Überzugsschicht des oberflächenbehandelten Metalls, dem Typ des Beschichtungswerkstoffes und der Form der Schweißwulst gesteuert werden.

Revendications

1. Un appareil laser pour le soudage d'un metal traité en surface (3a, 3b), revêtu d'une matière ayant une température d'évaporation inférieure à un point de fusion du métal traité en surface, en utilisant un faisceau laser à ondes pulsées ou continues (1), l'appareil laser comprenant : une unité d'alimentation de gaz (4a, 4b) pour fournir l'oxygène et un autre gaz en tant que gaz auxiliaire ; et une unité de projection de gaz auxiliaire (7, 8) pour projeter le gaz auxiliaire vers un point de soudage ; caractérisé en ce que l'appareil laser comprend un mélangeur de gaz (6) dans lequel l'oxygène et l'autre gaz sont mélangés avant d'être utilisés dans l'unité de projection de gaz auxiliaire (7, 8).

2. Un appareil selon la revendication 1, dans lequel l'autre gaz contient au moins un gaz parmi l'argon gazeux, l'hélium gazeux et l'azote gazeux.

3. Un appareil selon la revendication 1 ou la revendication 2, dans lequel l'oxygène gazeux et l'autre gaz sont fournis par l'intermédiaire de vannes de commande (30a, 30b), respectivement.

4. Un appareil selon la revendication 3, dans lequel la proportion de mélange de l'oxygène et de l'autre gaz et les débits de l'oxygène et de l'autre gaz sont chacun commandés par un degré d'ouverture des vannes de commande (30a, 30b).

5. Un appareil selon l'une quelconque des revendications précédentes, dans lequel les vannes de commande sont commandées par un dispositif CN (50).

6. Un procédé de soudage d'un métal traité en surface (3a, 3b), revêtu d'une matière ayant une température d'évaporation inférieure à un point de fusion du métal traité en surface, en utilisant un faisceau laser à ondes pulsées ou continues (1), dans lequel un mélange d'oxygène et d'un autre gaz est utilisé en tant que gaz auxiliaire pour la soudure ; caractérisé en ce que l'oxygène gazeux et l'autre gaz sont mélangés dans un mélangeur (6) avant d'être utilisés en tant que gaz auxiliaire.

7. Un procédé selon la revendication 6, dans lequel l'autre gaz est au moins un gaz parmi l'argon, l'hélium gazeux et l'azote gazeux.

8. Un procédé selon la revendication 6 ou la revendication 7, dans lequel le métal traité en surface est une feuille d'acier zingué (3a, 3b).

9. Un procédé selon l'une quelconque des revendications 6 à 8, dans lequel la proportion d'oxygène augmente avec l'augmentation de la vitesse de soudage.

10. Un procédé selon l'une quelconque des revendications 6 à 9, dans lequel la proportion d'oxygène augmente avec l'augmentation de la puissance laser.

11. Un procédé selon l'une quelconque des revendications 6 à 10, dans lequel trois feuilles (33a, 33b, 33c) de métal traité en surface sont superposées les unes au-dessus des autres et ensuite soudées de manière que la feuille de fond (33c) des trois feuilles superposées du métal traité en surface ne soit pas soudée.

12. Un procédé selon l'une quelconque des revendications 6 à 11, dans lequel le rapport de mélange de l'oxygène et de l'autre gaz, et les débits de l'oxygène et de l'autre gaz sont chacun commandés en fonction d'au moins l'épaisseur d'une couche de revêtement du métal traité en surface, du type de matière de revêtement et de la forme d'une chenille de soudure.

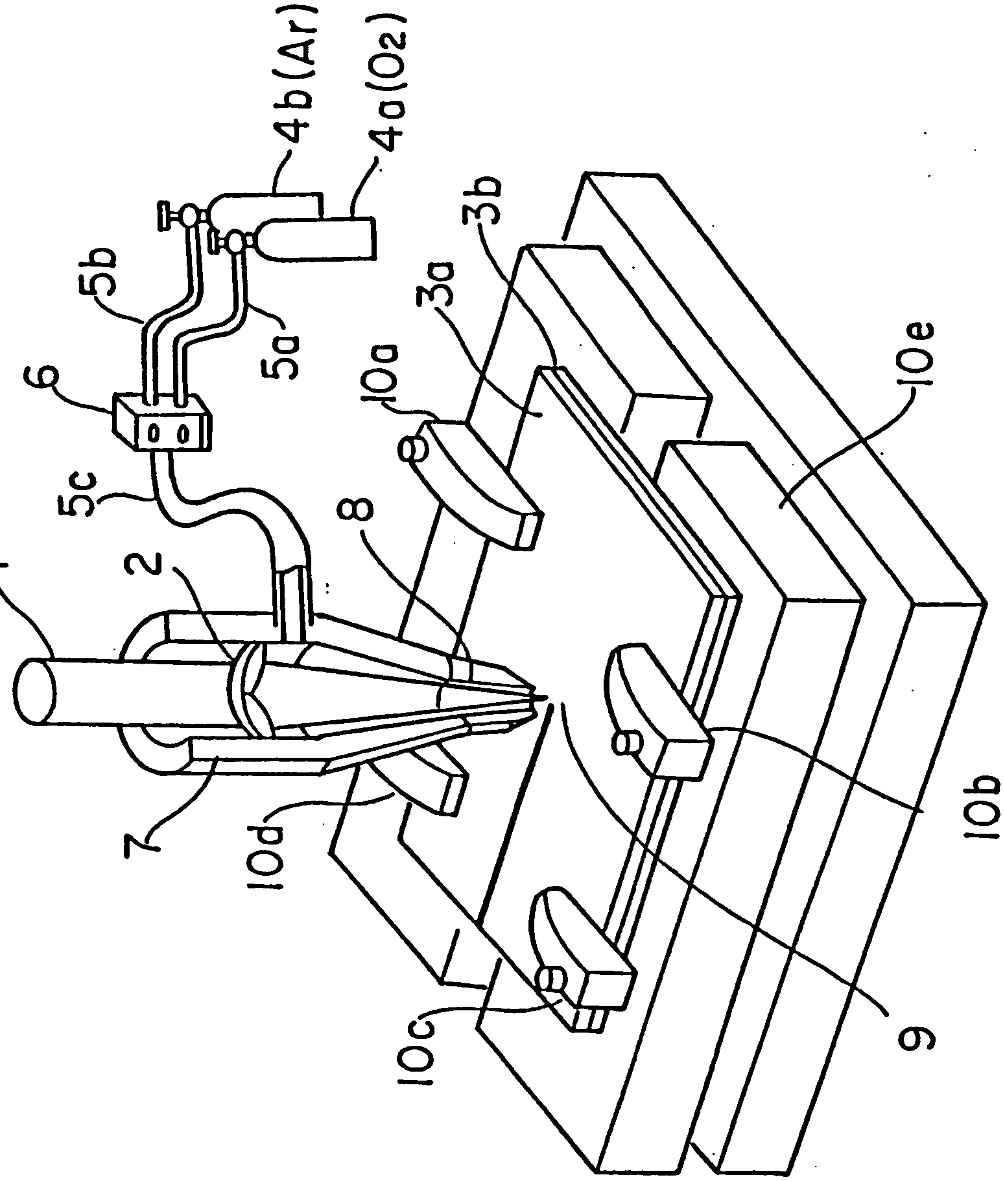


Fig. 1

Fig. 2 (A)

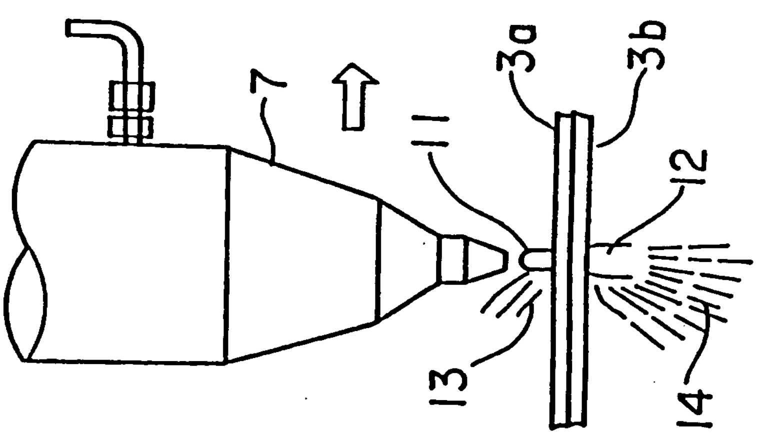


Fig. 2 (B)

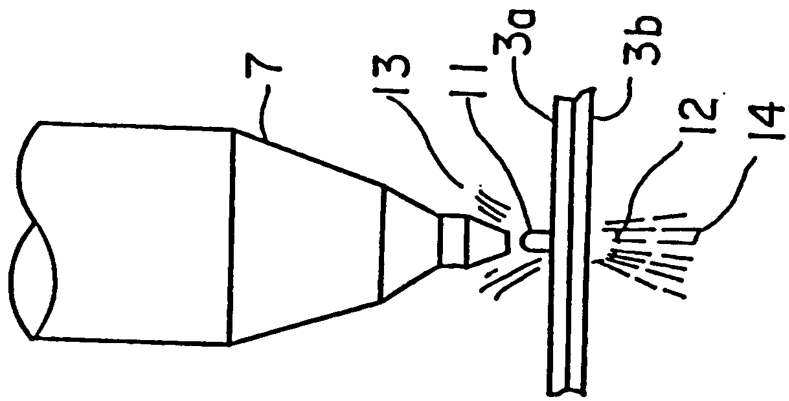


Fig. 3 (B)

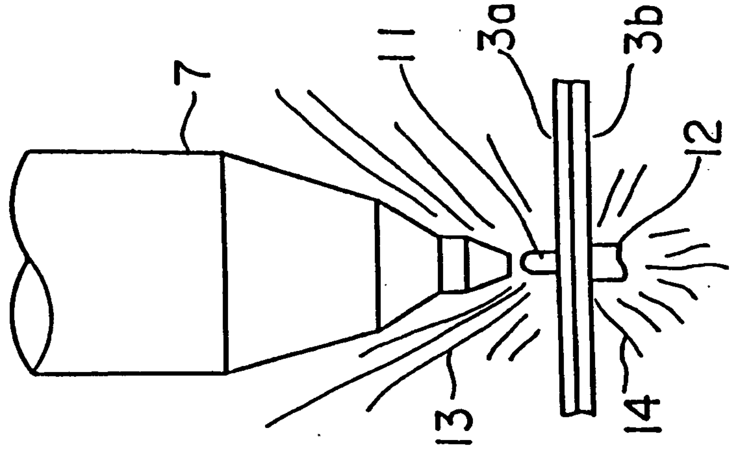


Fig. 3 (A)

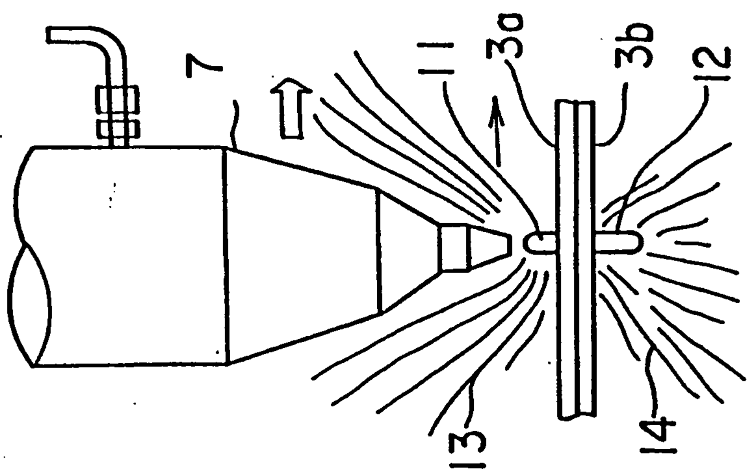


Fig. 4 (A)

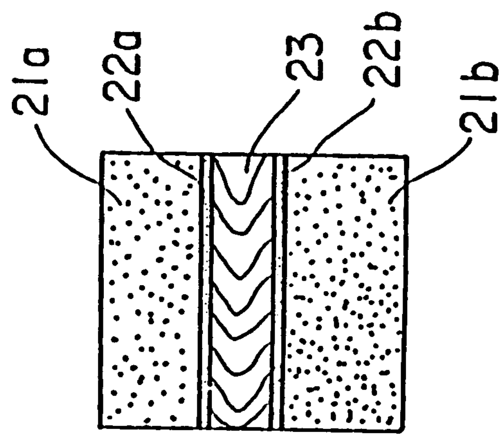
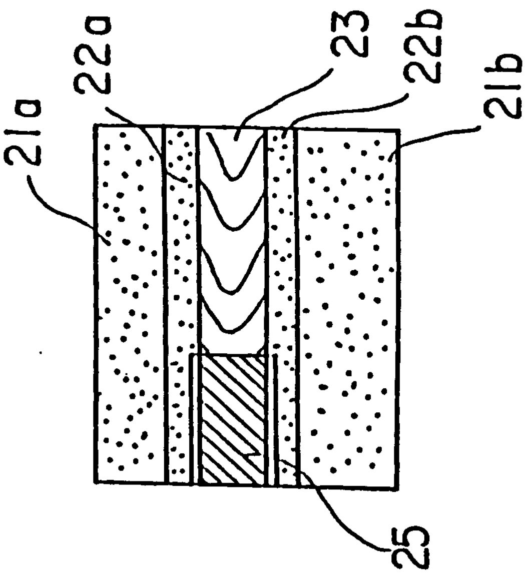


Fig. 4 (B)



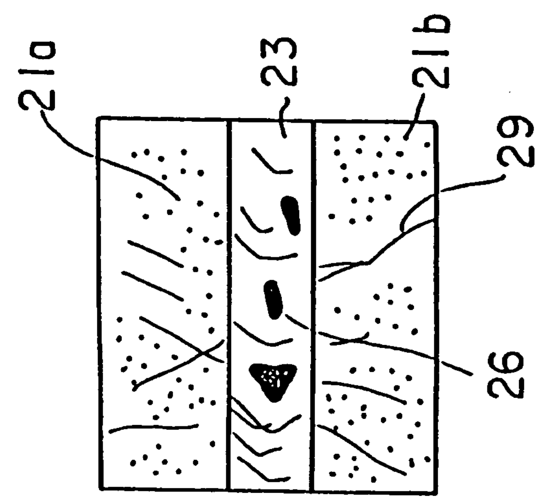


Fig. 5 (A)

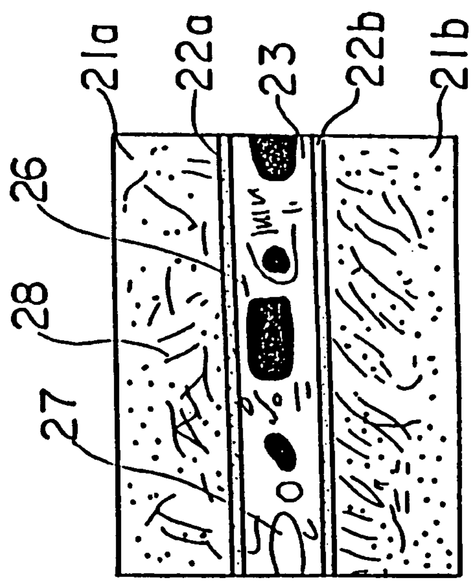


Fig. 5 (B)

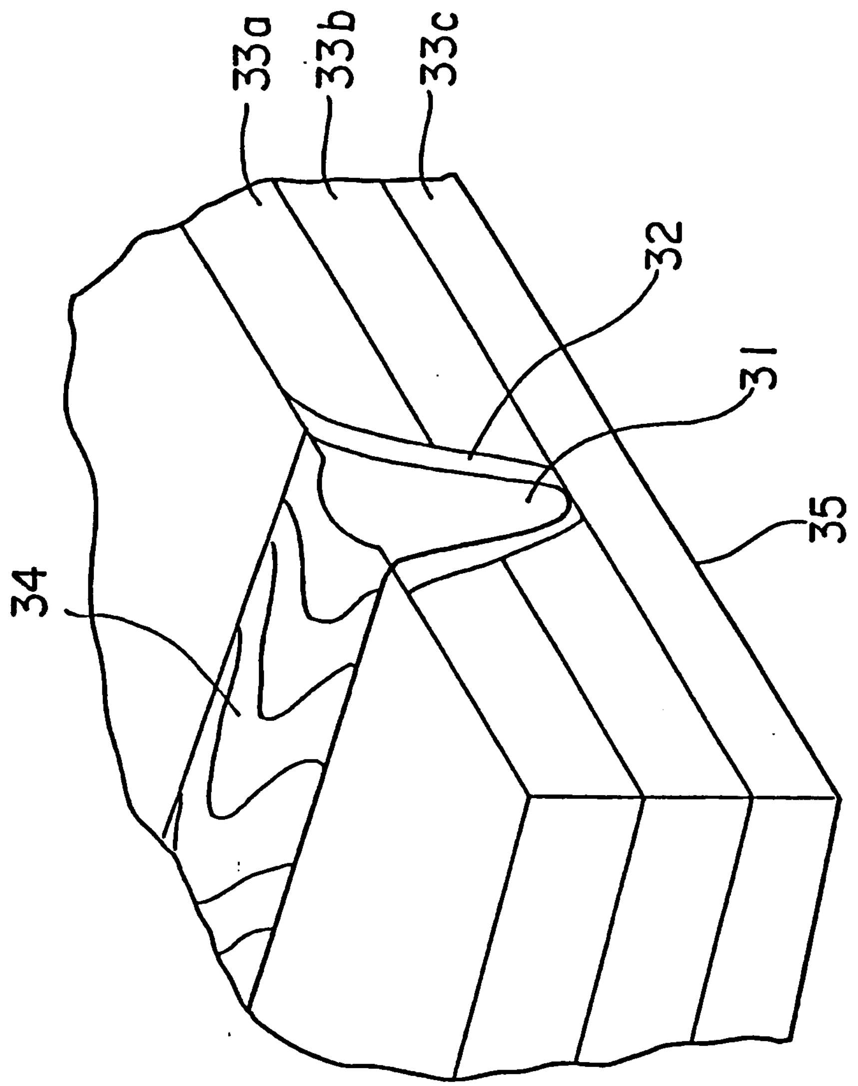
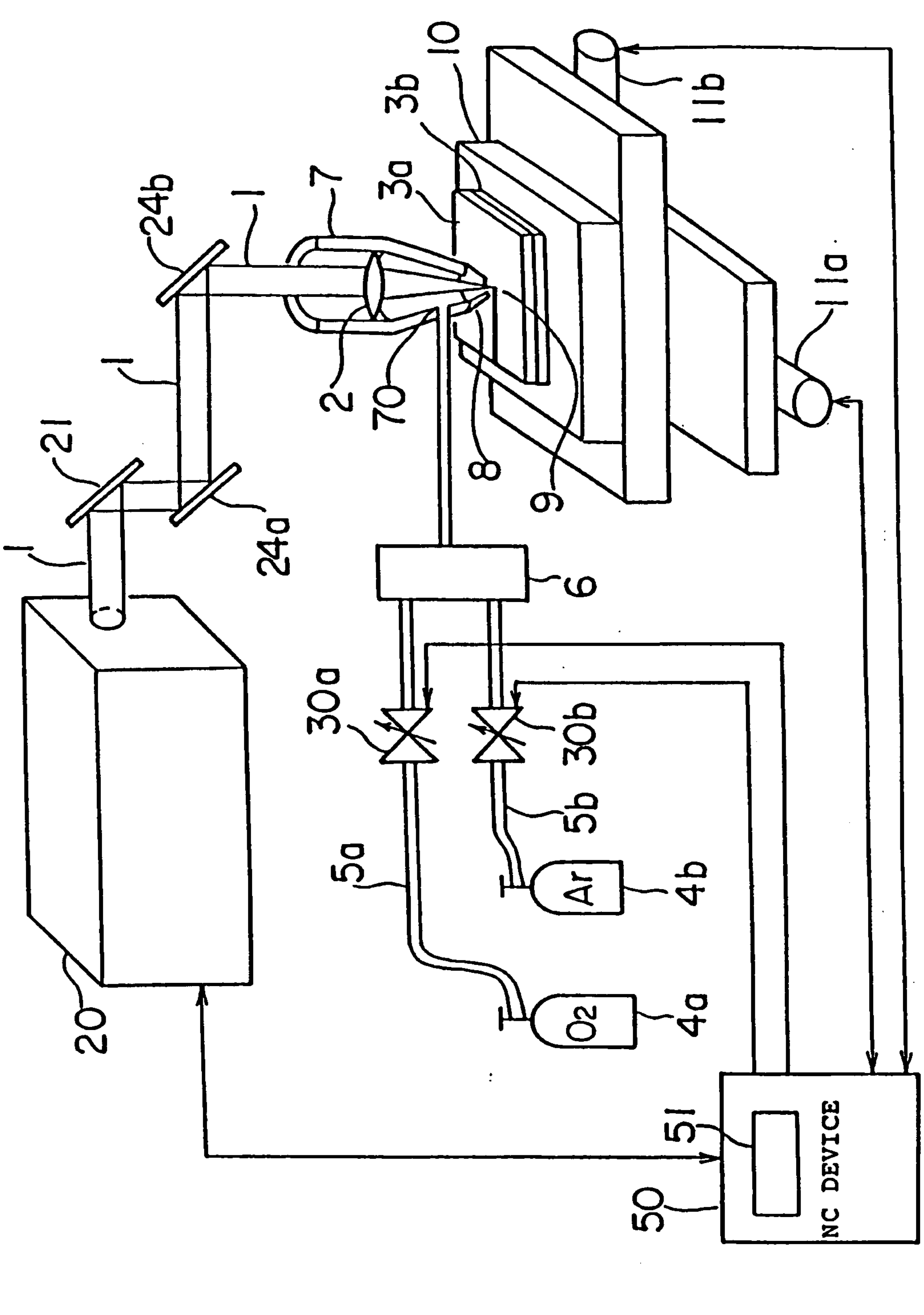
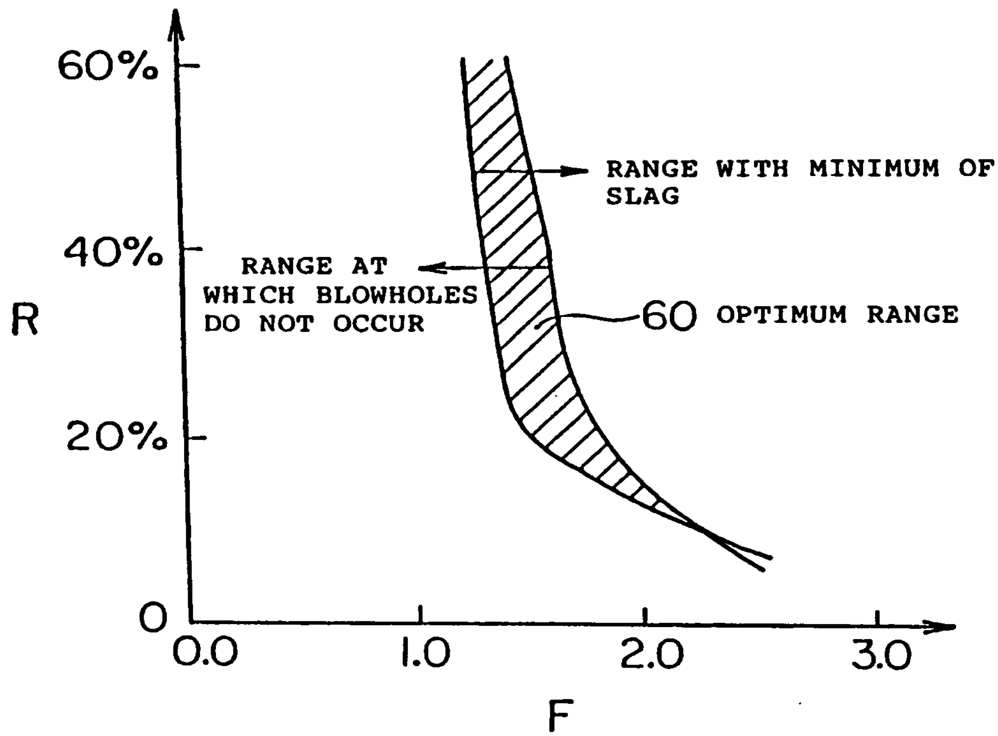


Fig. 6



1
2
3a
3b
4a
4b
5a
5b
6
7
8
9
10
11a
11b
20
21
24a
24b
30a
30b
50
51
70
O_2
Ar
NC DEVICE

Fig. 7


60%
40%
20%
0
R
RANGE WITH MINIMUM OF SLAG
RANGE AT WHICH BLOWHOLES DO NOT OCCUR
60 OPTIMUM RANGE
0.0
1.0
2.0
3.0
F

F i g . 8

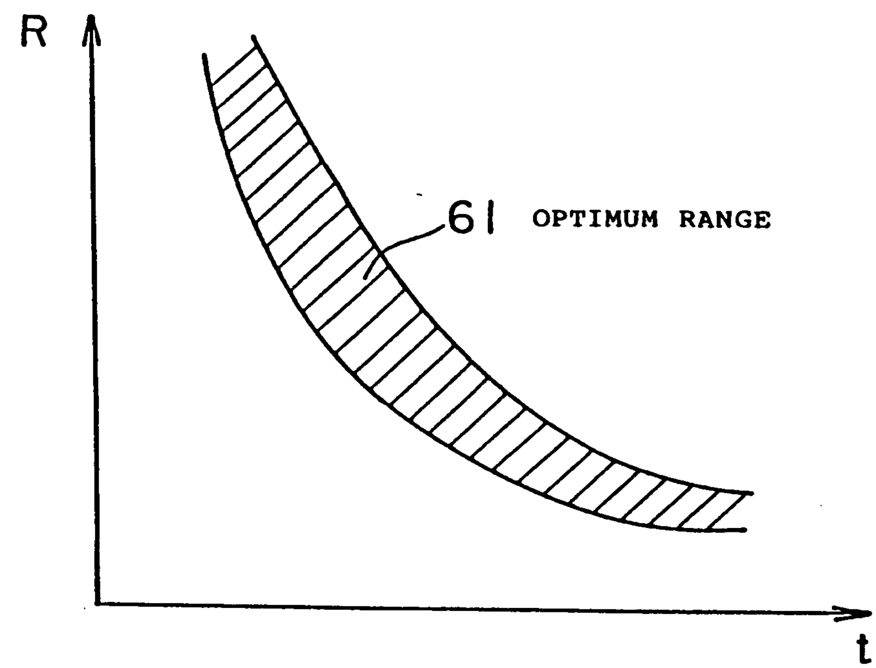


Fig. 9

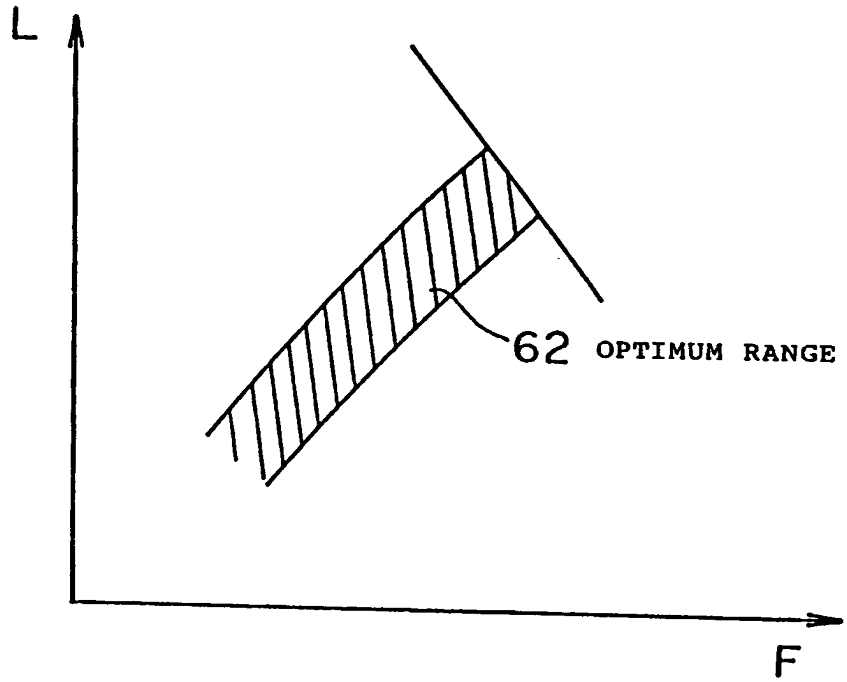


Fig. 10